

## 1.7 ATOMIC SCATTERING FACTORS

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The optical properties of materials in the photon energy range above about 30 eV can be described by the atomic scattering factors. The index of refraction of a material is related to the scattering factors of the individual atoms by

$$n = 1 - \delta - i\beta = 1 - \frac{r_e}{2\pi} \lambda^2 \sum_i n_i f_i(0) \quad , \quad (1)$$

where  $r_e$  is the classical electron radius,  $\lambda$  is the wavelength, and  $n_i$  is the number of atoms of type  $i$  per unit volume. The parameters  $\delta$  and  $\beta$  are called the refractive index decrement and the absorption index, respectively. The complex atomic scattering factor for the forward scattering direction is

$$f(0) = f_1 + if_2 \quad . \quad (2)$$

The imaginary part is derived from the atomic photoabsorption cross section:

$$f_2 = \frac{\sigma_a}{2r_e \lambda} \quad . \quad (3)$$

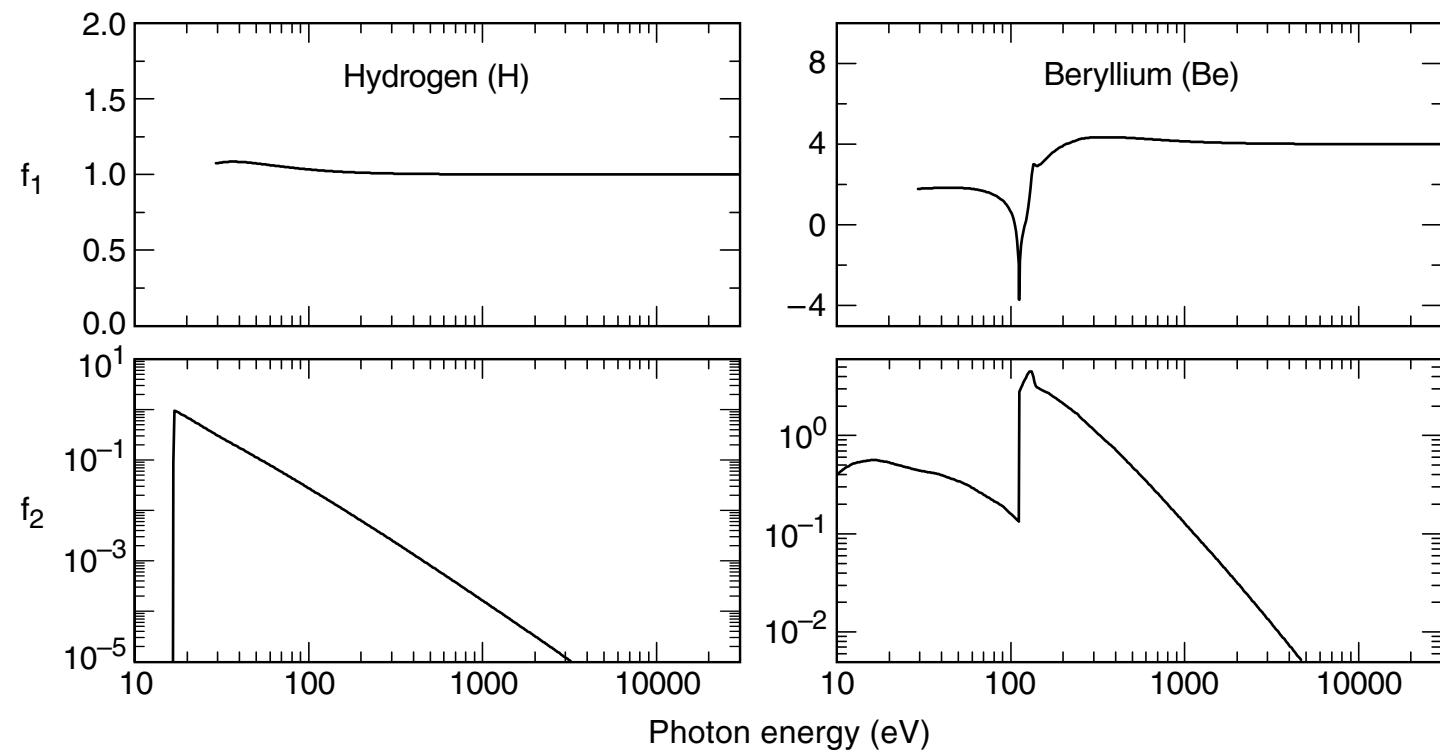
The real part of the atomic scattering factor is related to the imaginary part by the Kramers-Kronig dispersion relation:

$$f_1 = Z^* + \frac{1}{\pi r_e h c} \int_0^\infty \frac{\varepsilon^2 \sigma_a(\varepsilon)}{E^2 - \varepsilon^2} d\varepsilon \quad . \quad (4)$$

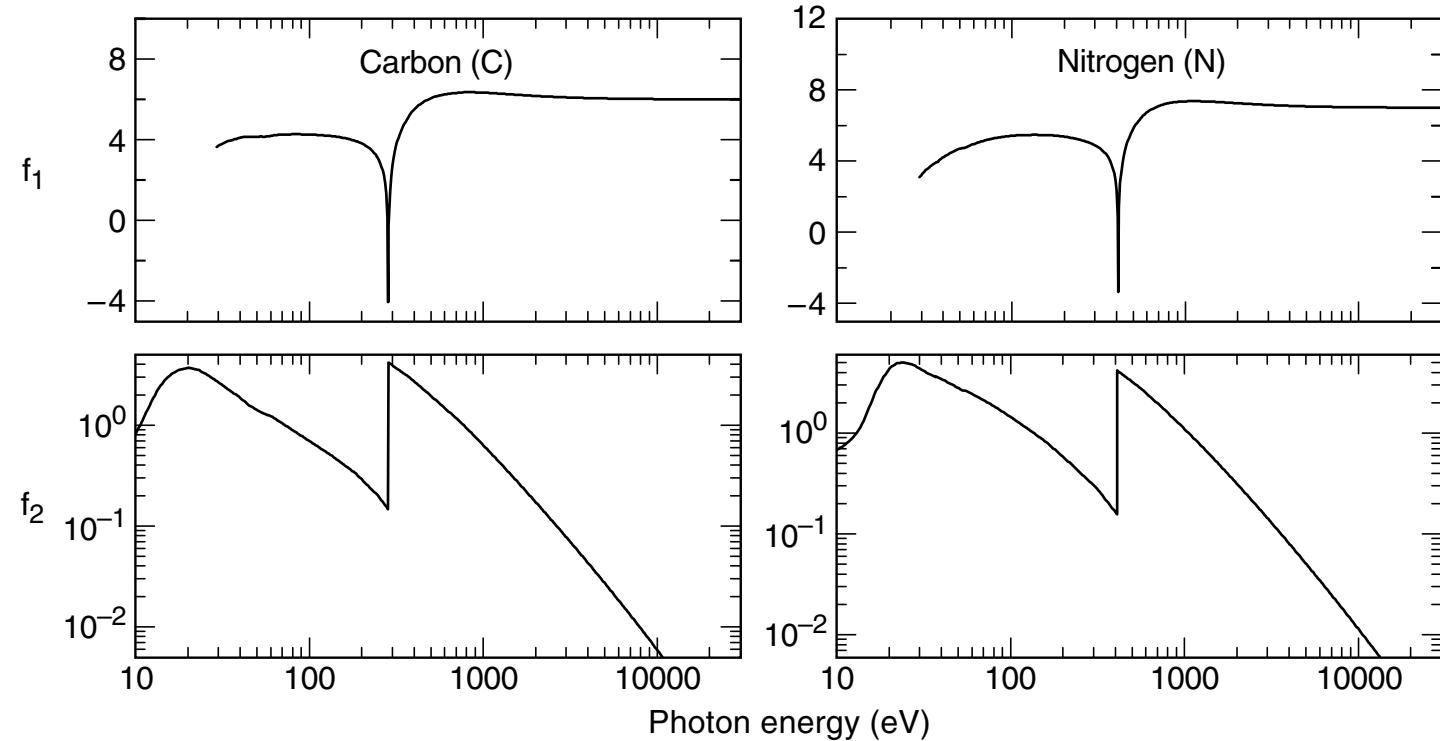
In the high-photon-energy limit,  $f_1$  approaches  $Z^*$ , which differs from the atomic number  $Z$  by a small relativistic correction:

$$Z^* \approx Z - (Z/82.5)^{2.37} \quad . \quad (5)$$

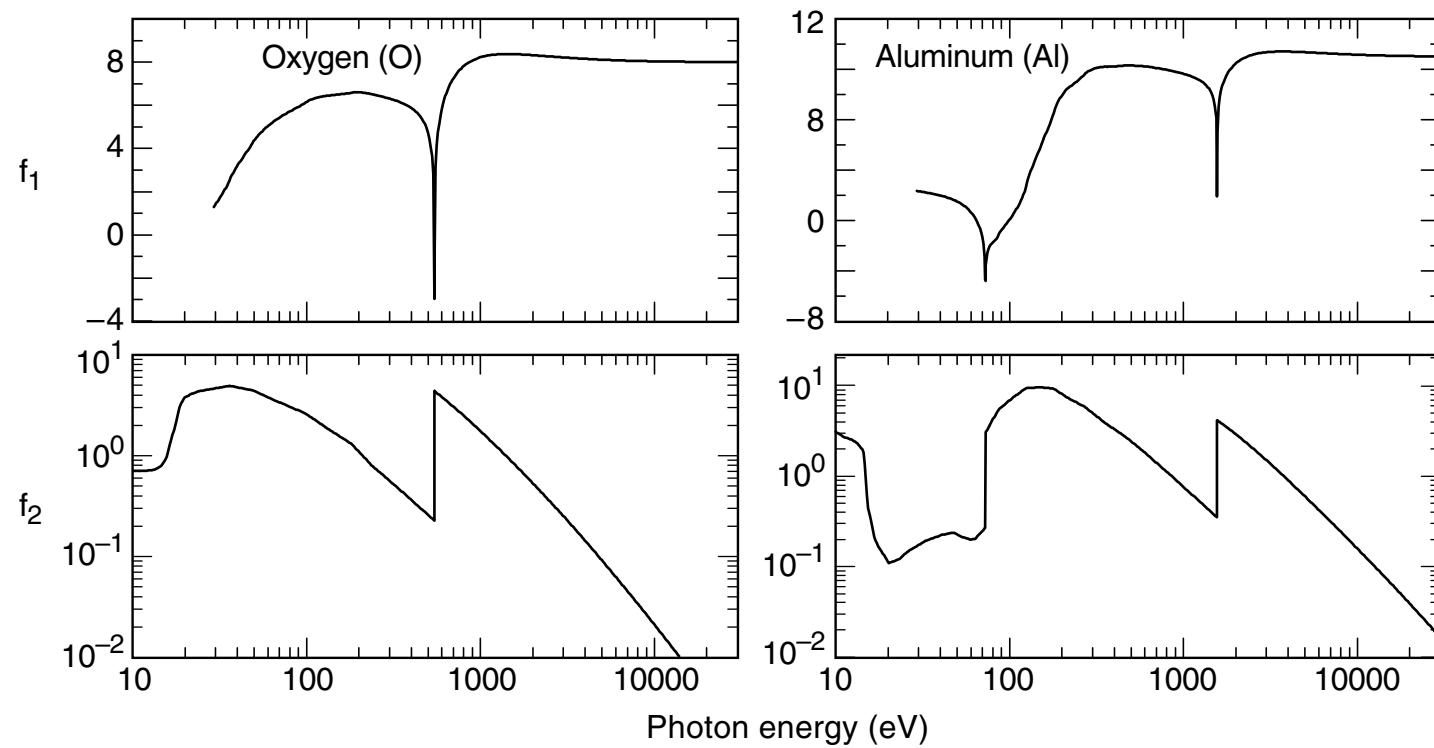
On the following pages, Fig. 1-6 presents the scattering factors for 15 elements in their natural forms. Complete tables of the atomic scattering factors are given in [See B. L. Henke, E. M. Gullikson, and J. C. Davis, ‘X-Ray Interactions: Photoabsorption, Scattering, Transmission, and Reflection at  $E = 50\text{-}30,000$  eV,  $Z = 1\text{-}92$ ,’ *At. Data Nucl. Data Tables* **54**, 181 (1993).] and on the web site [http://www-cxro.lbl.gov/optical\\_constants/](http://www-cxro.lbl.gov/optical_constants/).



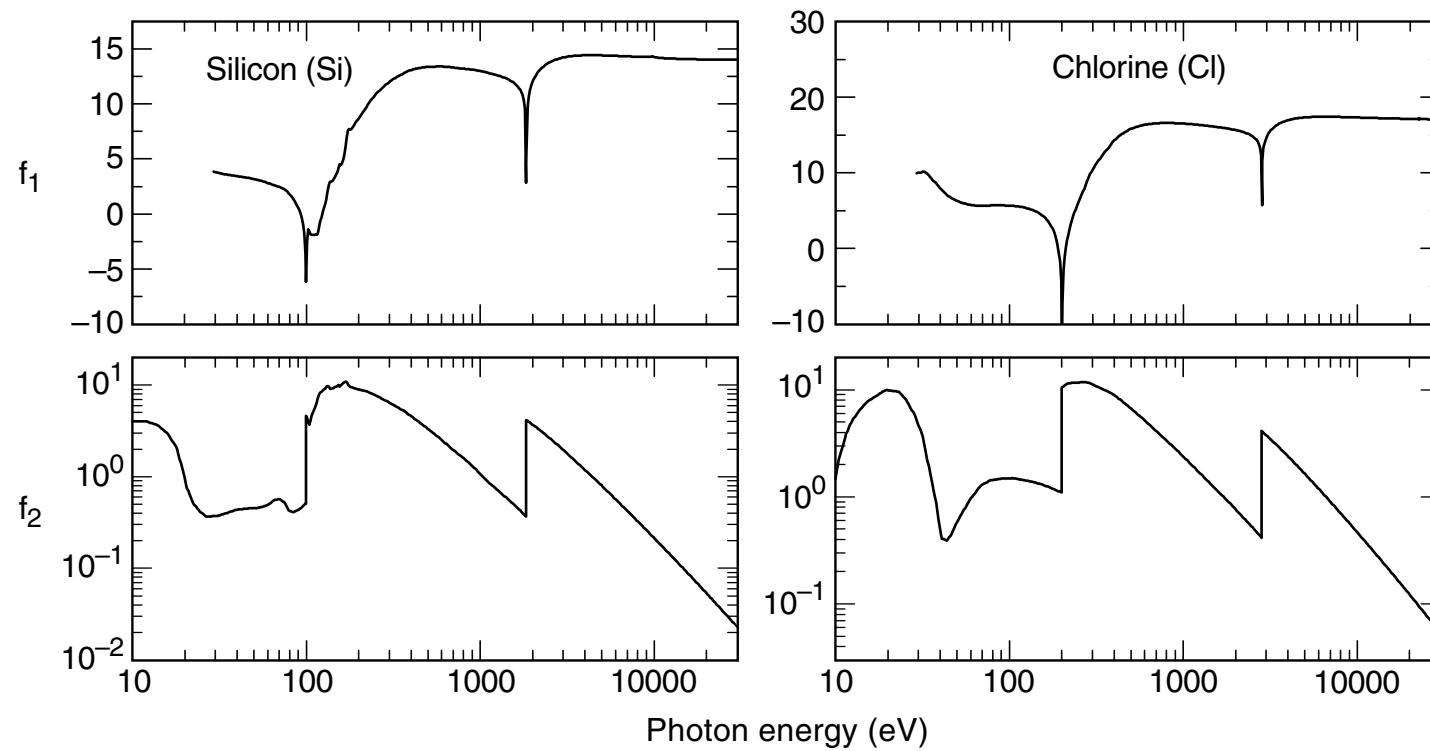
**Fig. 1-6.** Plots of scattering factors for several elements in their natural forms.



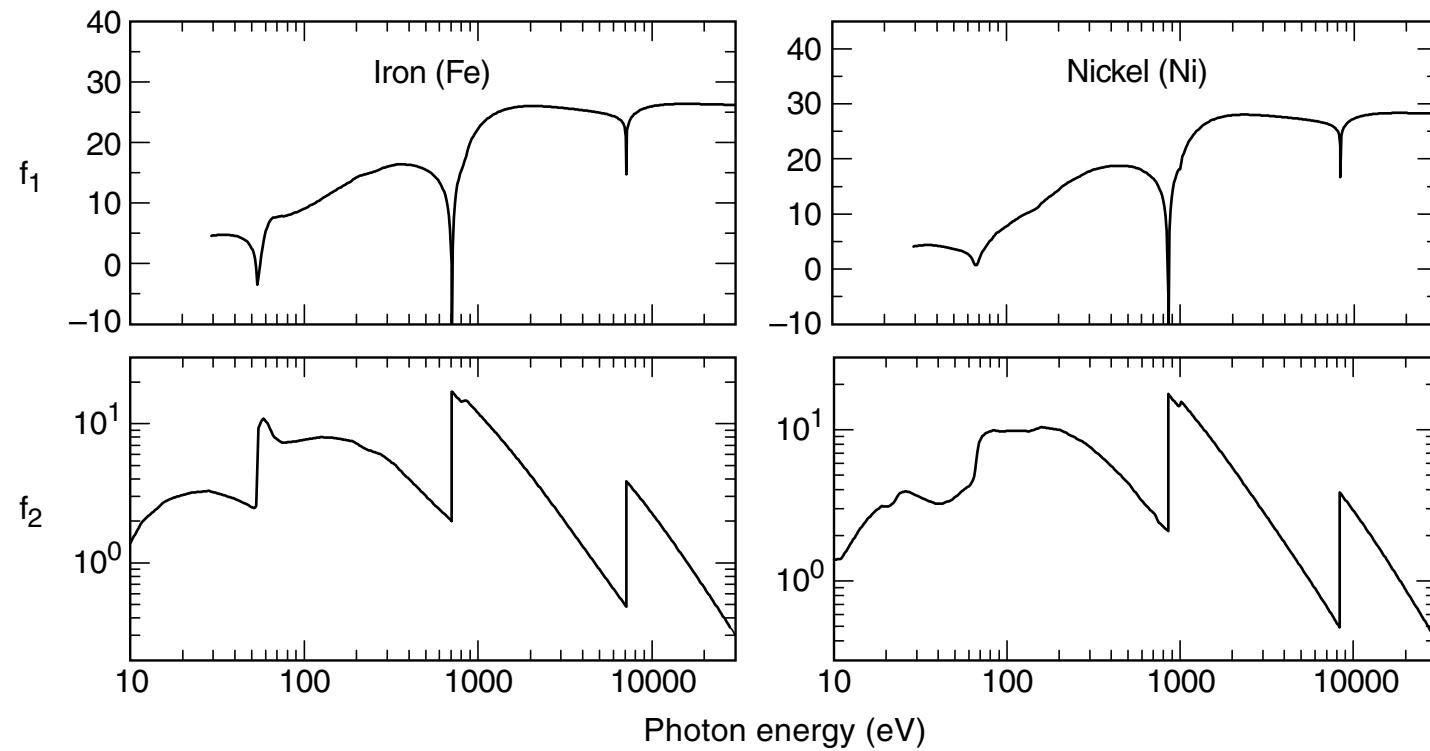
**Fig. 1-6.** Scattering factors (continued).



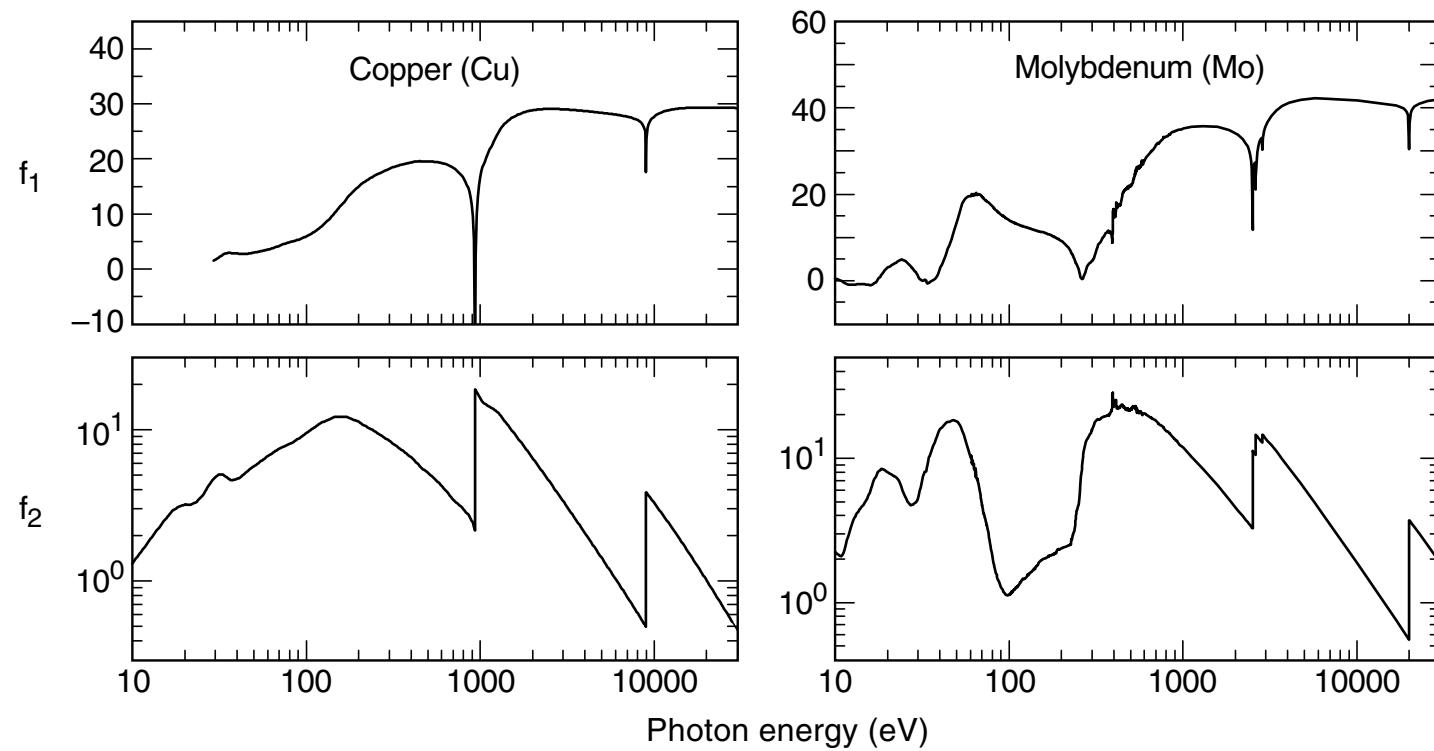
**Fig. 1-6.** Scattering factors (continued).



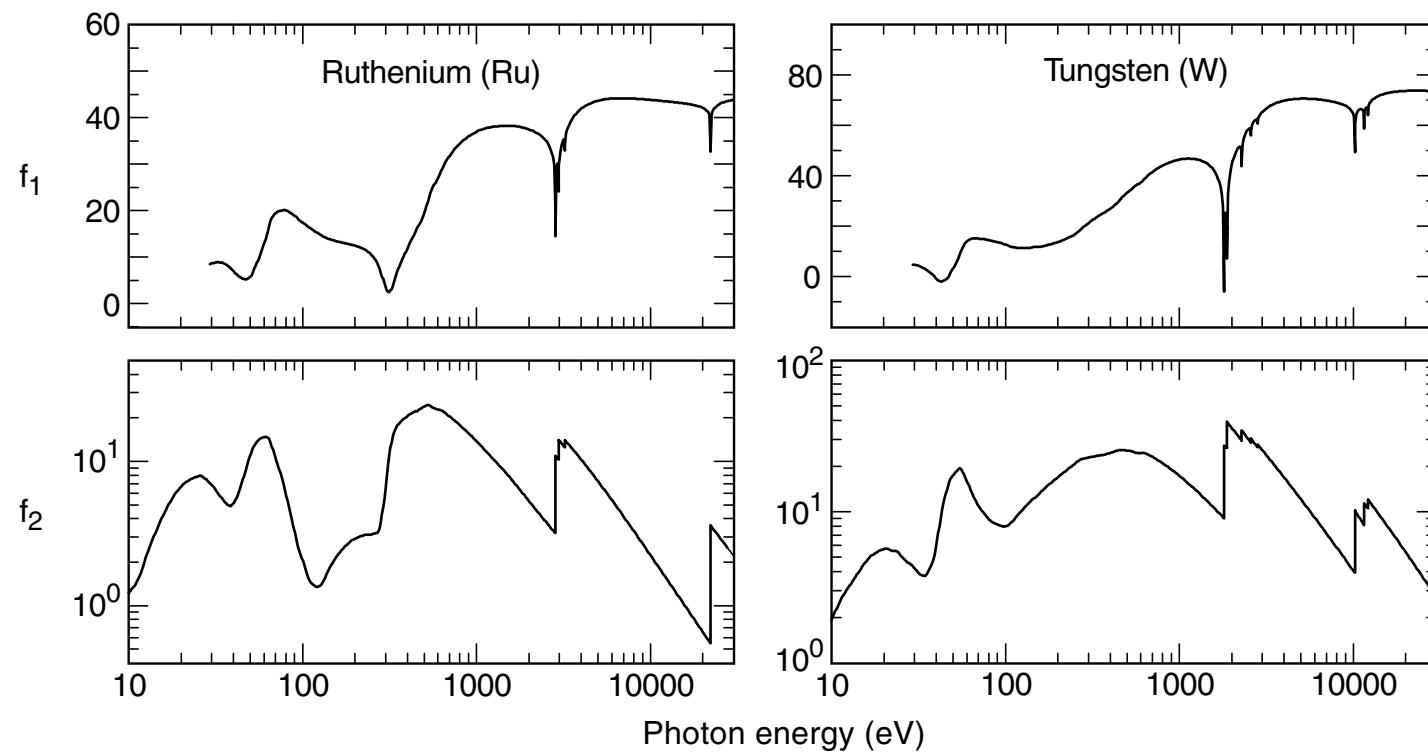
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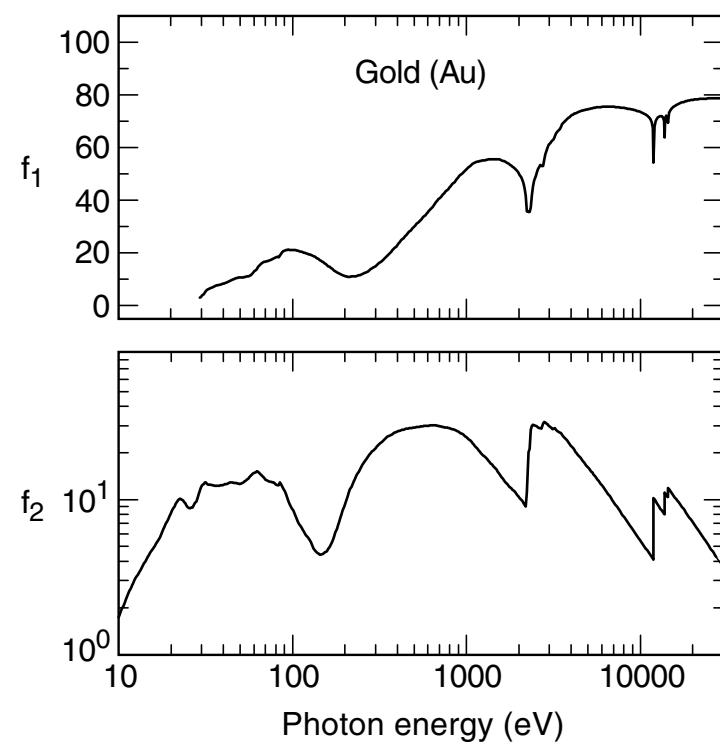
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*Fig. 1-6. Scattering factors (continued).*